

ECMWF operational model: the IFS

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IFS: Integrated Forecast System

Operational system at ECMWF

- Deterministic 10 day forecast ($T1279 \simeq 16\text{km}$ resolution) dispatched twice a day to the member states for synoptic scale forecasting activities and as lateral boundary conditions for LAM models (strong operational time constraints)
- EPS with 50+1 members at T639
- Monthly and seasonal forecasts (IFS coupled with NEMO)
- RE-ANALYSES (ERA40, ERA interim)

IFS/ARPEGE/ALADIN/AROME

- Global model at Meteo-France (stretched grid with rotated poles)
- Bi-periodic spectral LAM model (Aladin-Hirlam consortium, AROME)

IFS DyCores

Choices and design

“old fashion”, very efficient, very robust

Spectral, Eulerian, leap-frog, semi-implicit

⇒ Spectral, semi-implicit, semi-Lagrangian, two time levels

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Common characteristics

- Two-time levels, spectral, semi-implicit
 - “non finite volume” semi-Lagrangian advection, non-linear RHS and physics on a collocation grid (reduced Gaussian A-grid for the IFS)
 - hydrostatic pressure hybrid vertical coordinate (Simmons and Burridge, Laprise) — Finite differences or finite elements.
 - linear tangent and adjoint codes (4DVAR)
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- hydrostatic (operational IFS) or fully-compressible non-hydrostatic (Bubnova et al, 1995, Wedi et al, 2008)
 - ICI (predictor/corrector) scheme for dynamics (stability of NH-IFS)

IFS time step

- Inverse Legendre-Fourier Transforms
 - Non-linear “explicit” part of the dynamics: RHS of equations, semi-Lagrangian advections
 - Physics
 - Direct Fourier-Legendre Transforms
 - Spectral computations : solver for semi-implicit correction, numerical diffusion, gradient computations (pressure gradient force)
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- Time split (sequential) both for physics/dynamics coupling and inside the physics,
 - Semi-Lagrangian averaging of some (slow) physics tendencies along the SL trajectories.

IFS prognostic variables

Spectral space

- $VOR, DIV, R_h T = R_d T_v, \pi_s,$
- $d_4, \hat{q} = \ln(p/\pi)$

Grid point space

- $(VOR, DIV)/(U, V), T, \pi_s,$
- $d_4/gw (+X), \hat{q}$
- $q_v, q_l, q_i, q_r, q_s + \text{cloud fraction}$
- q_{O_3}, q_{CO_2} and many more if coupling with chemistry

IFS Dycores are “moist” Dycores:

$$R_d T_v = R_h T = [R_d + (R_v - R_d)q_v - R_d(q_l + q_i + q_r + q_s)]T, c_{p_h}$$

\Rightarrow buoyancy of moist air and water loading

with some inconsistencies: some parametrizations use dry c_p , precipitation mass flux compensated by a flux of dry air, “anelastic” physics/dynamics coupling in NH-IFS...

Is the IFS design so old fashion?

Global 12 hour NH forecast at T8000 ($\delta x \simeq 2.5 \text{ km}$) (Nils Wedi, last week...)

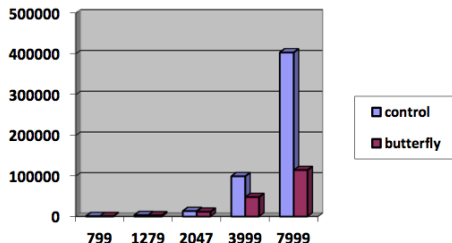
Fast Legendre Transforms

Nils Wedi, Mats Hamrud, George Mozdzyński

FLT : Butterfly algorithm

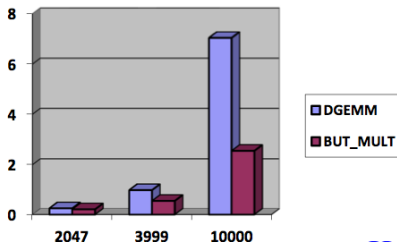
Floating point operations
per time-step in Gflop

**Inverse transform of
single field/level**

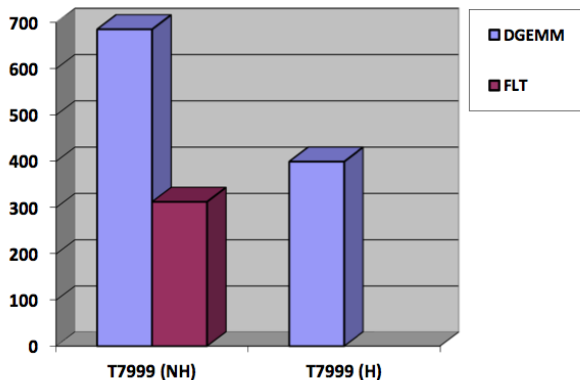


Wallclock time in seconds

**(Simulated) simultaneous
inverse transforms of 10 fields**

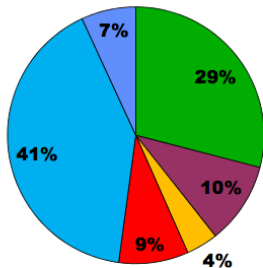


Wall-clock time computational cost of the direct and inverse spectral transforms during a 1hour simulation at T7999



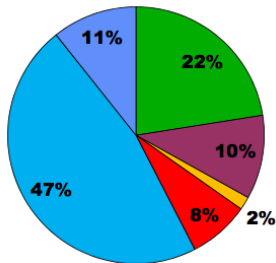
Notably, the hydrostatic (H) simulation has 2 prognostic variables less to transform and no ICI iteration, more than halving the number of transforms compared to the non-hydrostatic (NH) simulation.

Computational Cost: H T2047 and H at T1279



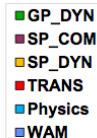
H T_L2047 L91

Tstep=450s, 1.6s/iteration
With 896x16 ibm_power7

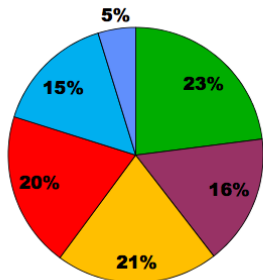


H T_L1279 L91

Tstep=600s, 2.8s/iteration
With 192x8 ibm_power7

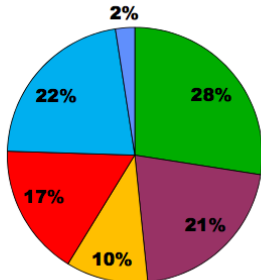


Computational Cost: NH at T2047 and T3999 with 137 vertical levels



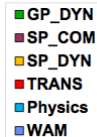
NH T_L3999 L137

Tstep=240s, 8.5s/iteration
With 896x16 ibm_power7



NH T_L2047 L137

Tstep=450s, 2.2s/iteration
With 896x16 ibm_power7



On going works...

Conservation aspects

- Mass fixers (for chemistry, MACC project)
- Eulerian flux form scheme as reconstruction operators for the Semi-Lagrangian scheme (bi-focal SL/Eul glasses!)

Simpler equations for NH

Unified equations (Arakawa and Konor, 2009) for the IFS?

our dream : no ICI scheme, no "X" term, simpler coupling with physics...

Modern Computer Science

- Dis-Integration of the I.F.S : OOPS project \Rightarrow C⁺⁺ layer driving both the assimilation systems and the model (to start with...)
- Fortan Coarrays (CRESTA PROJECT)

At ECMWF, on a little (moist!) planet...



Small planet

- instead of a LAM model for convection resolving studies (dry and moist bubbles, splitting storms) and NH orographic dry and moist waves,
- Dry Held and Suarez, dry baroclinic waves,

but, can we reproduce the (moist) climate on a small planet and then study the transition between parametrized and resolved convection? \Rightarrow EMBRACE project (P. Bechtold, N. Semane, S. Malardel)

- reduce the gap between large balanced scales and convective scales (if gravity kept constant)
- what happen when there is no gap (test case 413?)

Sharing our planet

OPEN-IFS for universities and education, to come soon...